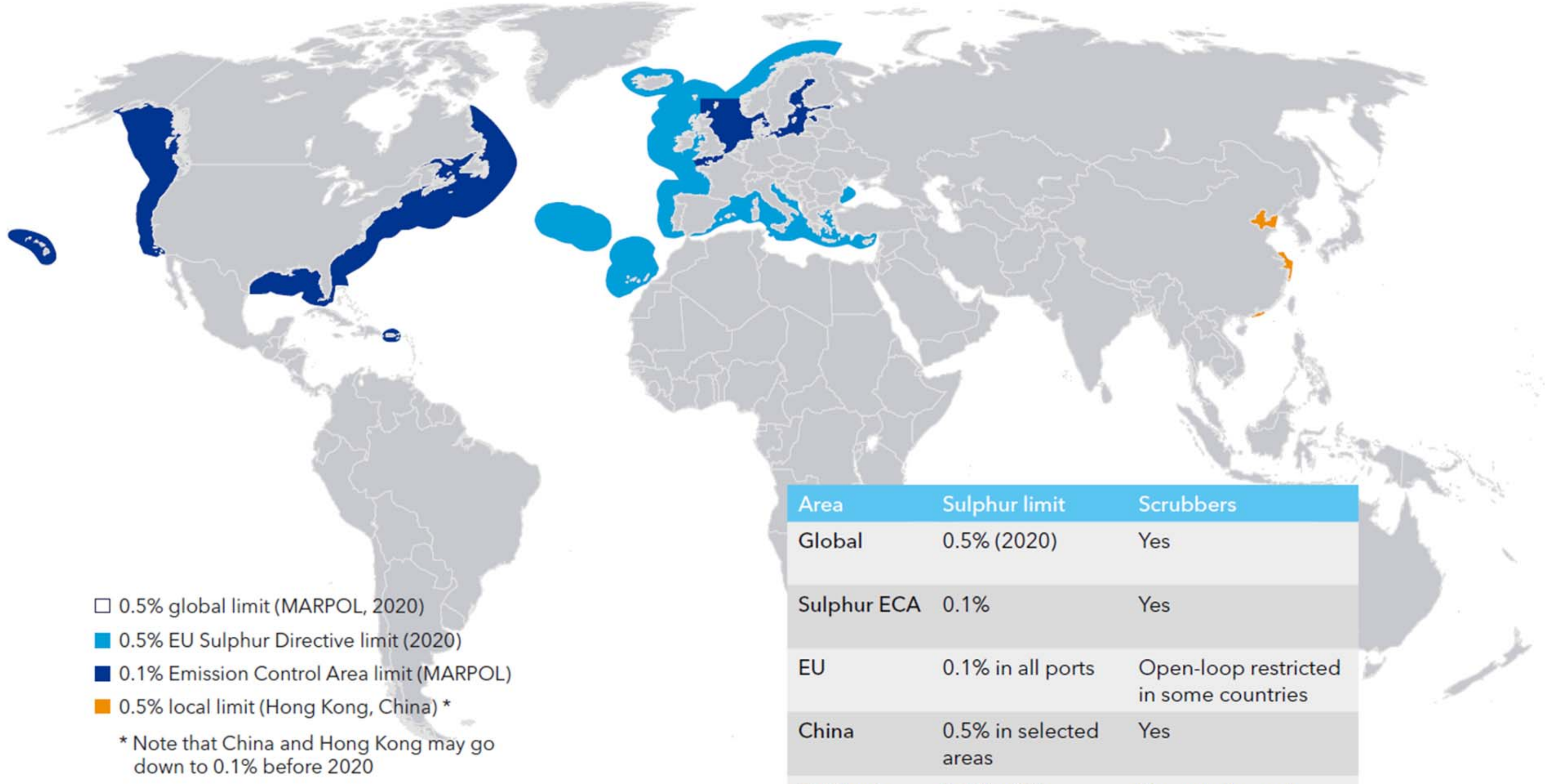
Blue INNOship Project no. 7

Agenda

Introduction
Emission Regulations

Future regulations demand reduced sulphur emissions.

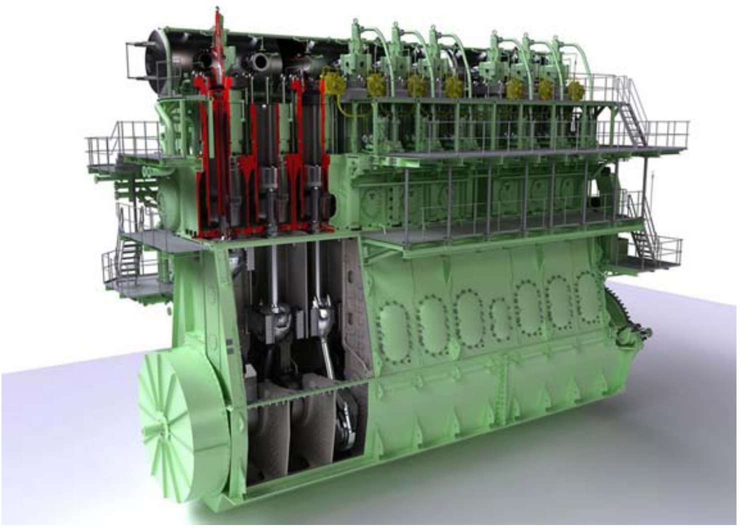
Various fuel gasses will be utilised in order to meet the requirements.



Area	Sulphur limit	Scrubbers
Global	0.5% (2020)	Yes
Sulphur ECA	0.1%	Yes
EU	0.1% in all ports	Open-loop restricted in some countries
China	0.5% in selected areas	Yes
California	0.1% within 24 nm	No, only through research exemption

Introduction

Emission Reductions



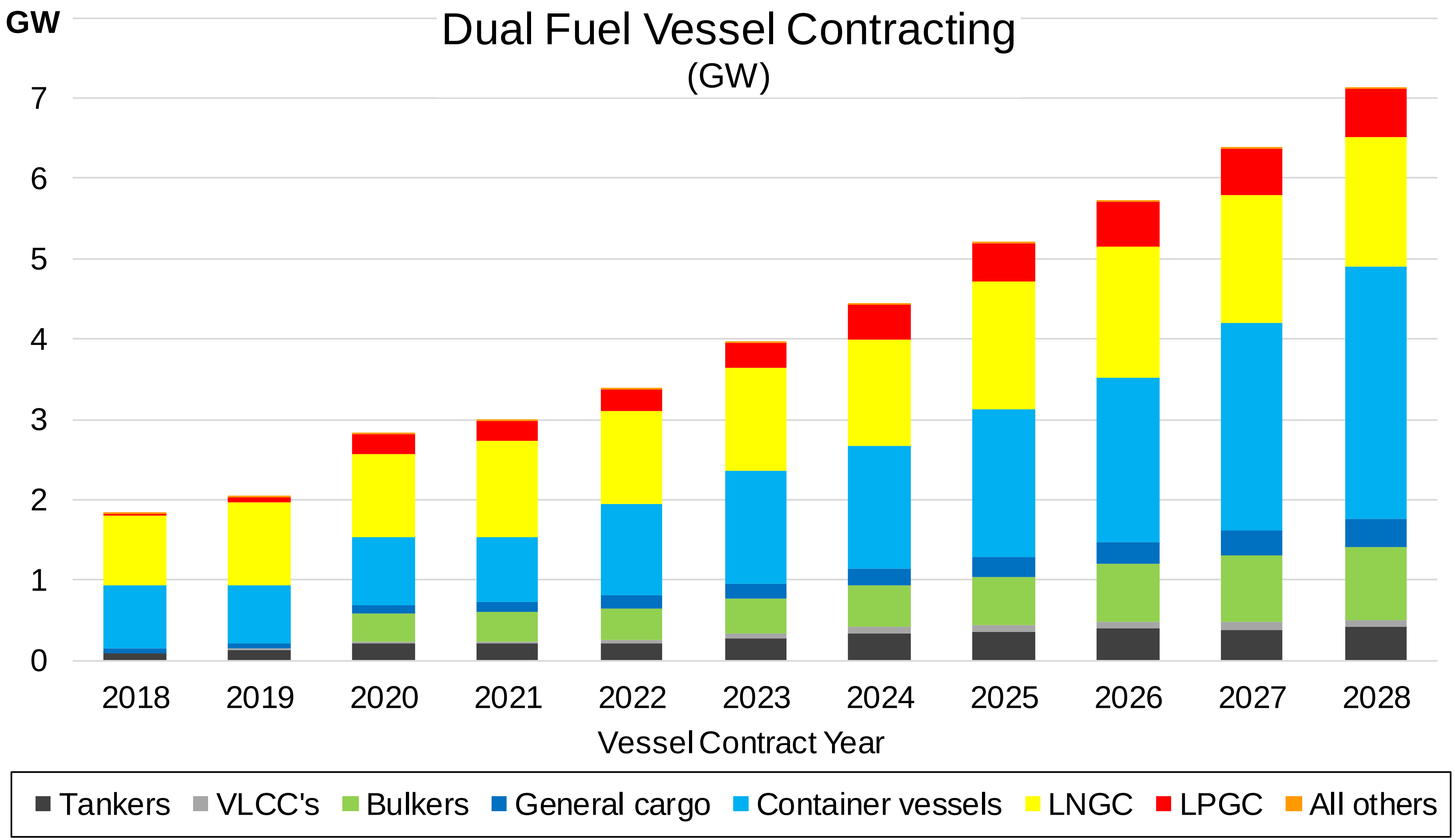
- **Energy efficiency**
- **Emission reduction**
- **ECA compliance**

Expected impact from the project:

- Increasing the gas injection pressure to 60 MPa, improves engine efficiency with app. 3% and opens the possibility of combusting several alternative gasses such as ethane and propane.
- When more ships are fuelled by various gasses, it reduces the CO_2 emissions from global shipping and lower the emissions of pollutant substances.
- MAN has shown that a gas engine emits 20-30% less CO_2 than a traditional HFO engine. In addition to this benefit, the gas engine has less NOx emissions and almost zero SO_2 emissions.

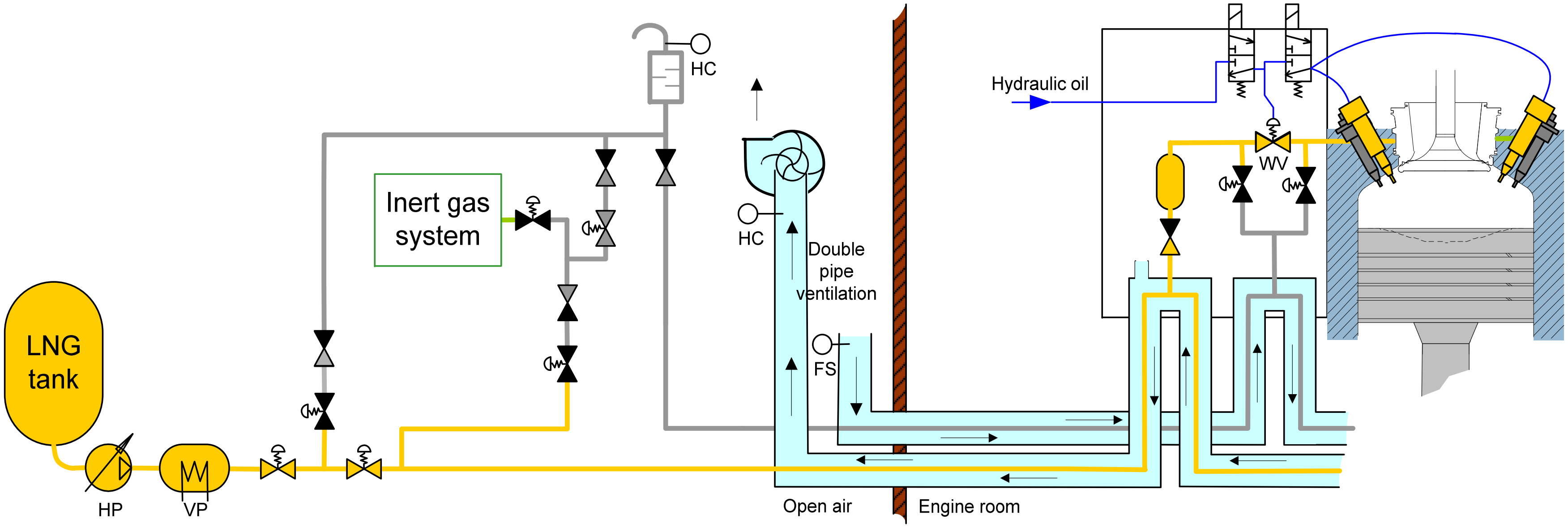
Introduction

Vessels Contracting Trends



Jan 2018 Source: FMS/Dept EELC

System description: Double wall pipes and ventilation system



Introduction

Partners of Blue INNOship Project no. 7

Partners of Blue INNOship Project no. 7:

Eltronic FUELTECH

MAN

AALBORG UNIVERSITY DENMARK

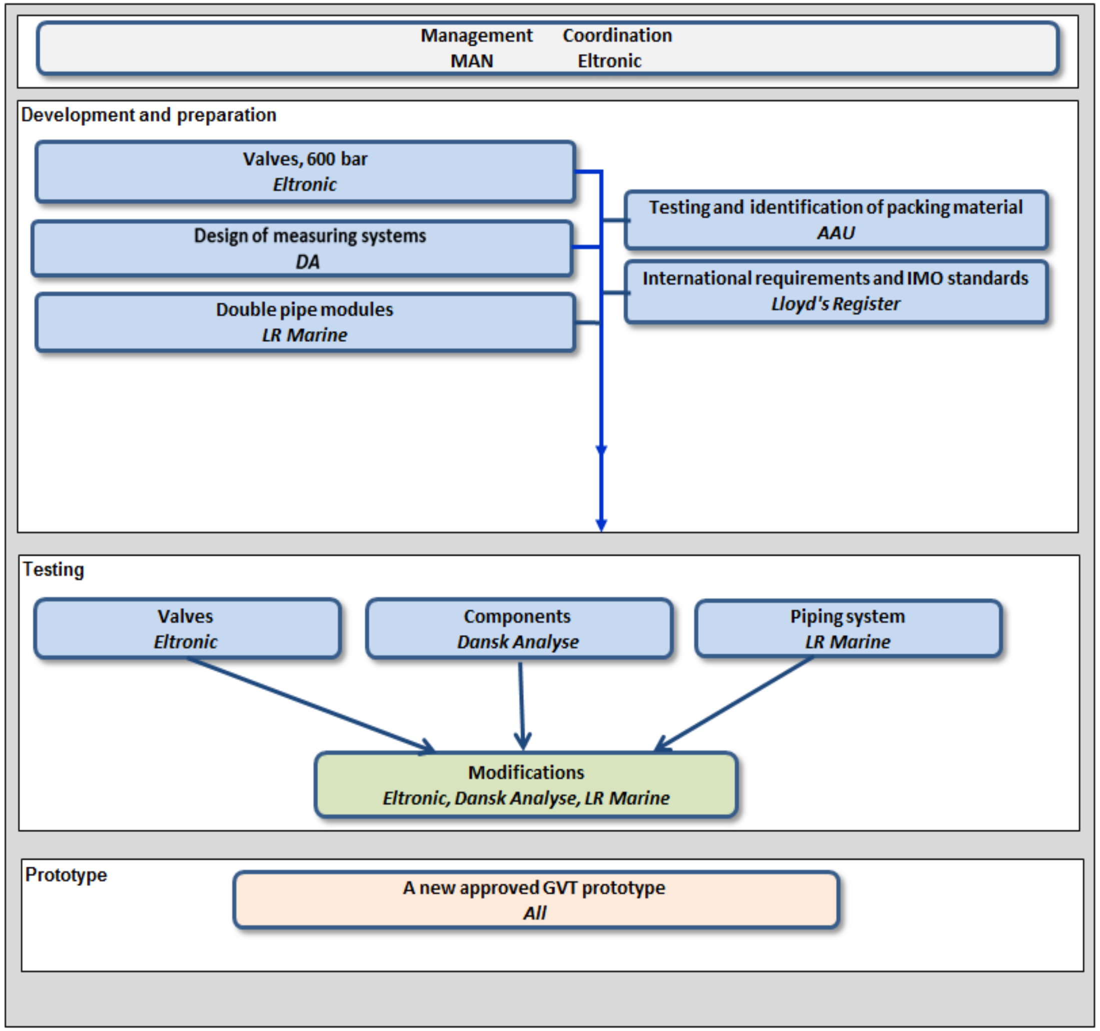
Lloyd's Register Marine

dansk analyse a·s

LR-MARINE MARINE & INDUSTRIAL SOLUTIONS PROVIDER

Project Organisation

Partners, Management & Tasks



Project Charter

Project: Gas Valve Train

Project	Gas valve train (GVT)
Goal	The overall goal is to increase the pressure of gas injected to two-stroke engines from 30 MPa to 60 MPa.
Objectives	A new GVT will be developed to enable the use of a higher gas pressure in two-stroke gas engines. The GVT is a complex technology and each part has to be developed for a higher gas pressure and all should be working together. The GVT will be jointly developed by a Danish consortium, that after the end of the project has a strong basis for export to engine manufacturers in Asia.
Key Milestones	1.: Mount of small-scale double pipe system at MAN test facility in Copenhagen. 2.: Incorporate flow measurement into engine control system, to optimise energy consumption. 3.: Test of prototype 60 MPa valve at MAN test facility in Copenhagen. 4.: Gas-slip detection to be made in double pipe system, refer to point 1. 5.: Test of alternative packing materials at test site, monitor wear and lifetime. 6.: Full scale test, validation and verification of new designed GVT, according to specific class standard. (DNV/ABS/etc.) 7.: Measurements and simulations to be made during design phase of new 60 MPa gas valve train. Especially focus on flow optimisation/pressure drop inside the GVT.
Project Risks	Unseen problems with materials and design during test. Redesign needed, and therefore the timeline might be exceeded. Materials and equipment for 60 MPa pressure will be so expensive that it will be commercially difficult to find customers for the final solution.

Tasks

Project: Gas Valve Train

Project Tasks	Description	Task Leader	Partners Involved
Double wall piping modularised concept	Developing a system that can easily be installed and serviced	LR Marine	LR Marine Dialogue with Eltronic and MAN. Testing at MAN
Gas valves	Changing the technology to a higher pressure	Eltronic	AAU MAN
Construction of gas valve train	Production of a prototype	Eltronic	MAN Lloyd´s Register
Criteria and standards	Risk analyses of GVT and components. Approval of GVT	Lloyd´s Register	Eltronic MAN
Measurements and simulations	CFD simulation of GVT models and components	AAU Energy	Eltronic MAN
Sealing materials	Testing of sealing materials and recommendation of suitable solutions	AAU Bio	Dialogue with Eltronic and MAN. Tests at Eltronic

Tasks

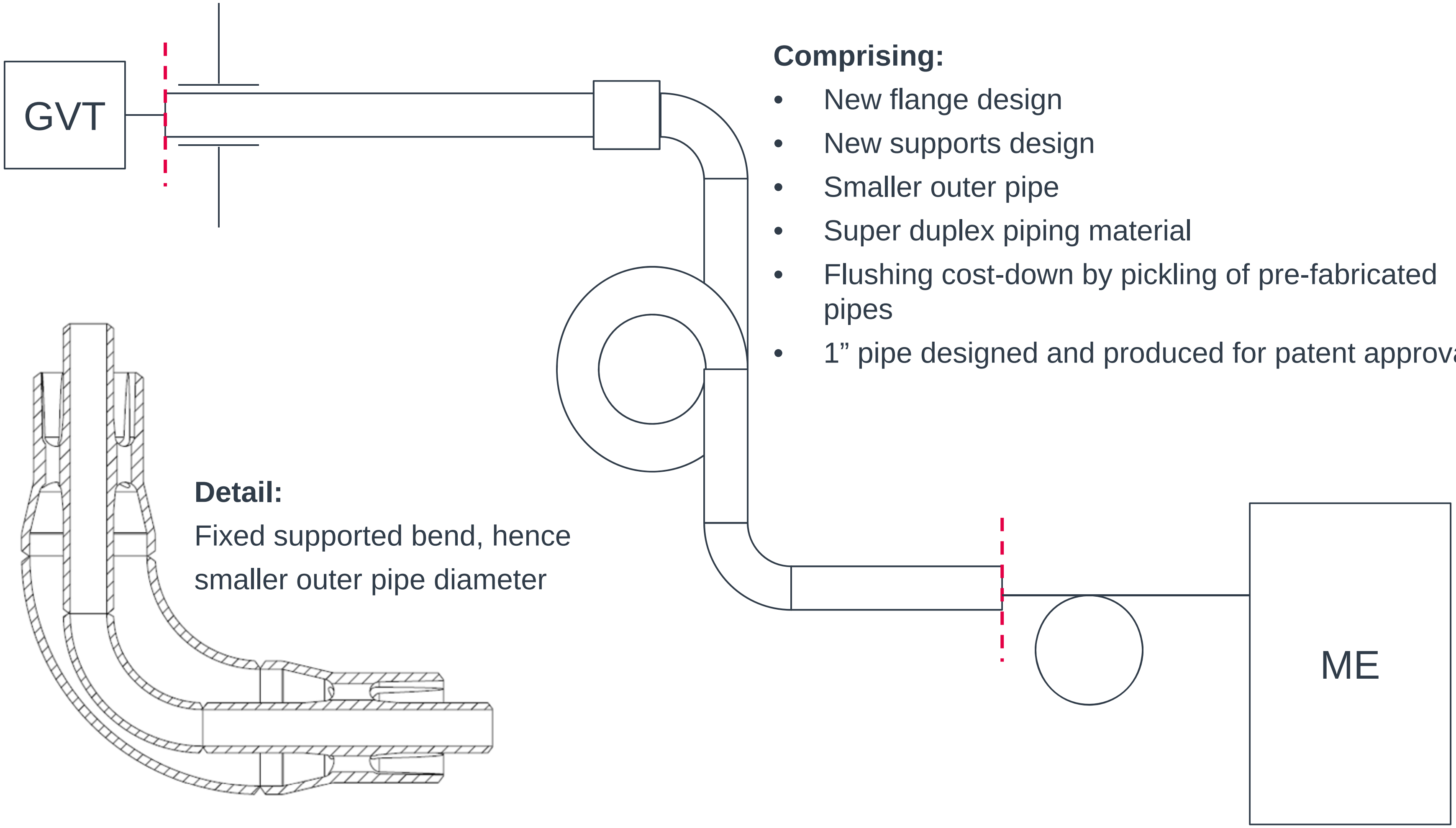
Project: Gas Valve Train

Project Tasks	Description	Task Leader	Partners Involved
Gas analyser	Changing the technology to a higher pressure	Dansk Analyse a/s	Eltronic MAN
Gas flowmeter	Changing the technology to a higher pressure	Dansk Analyse a/s	Eltronic MAN
Gas leak detection	Development of new gas leak detection technology	MAN	MAN
Test, validation and verification	Test of main components and the entire system	MAN	All partners
Management and cooperation	Overall management of technical progress as well as administration	MAN	Eltronic technical coordination and supervision

Tasks

60 MPa Optimised Design - MAN Double Wall Pipes

Supply pipe



Comprising:

- New flange design
- New supports design
- Smaller outer pipe
- Super duplex piping material
- Flushing cost-down by pickling of pre-fabricated pipes
- 1” pipe designed and produced for patent approval

Detail:

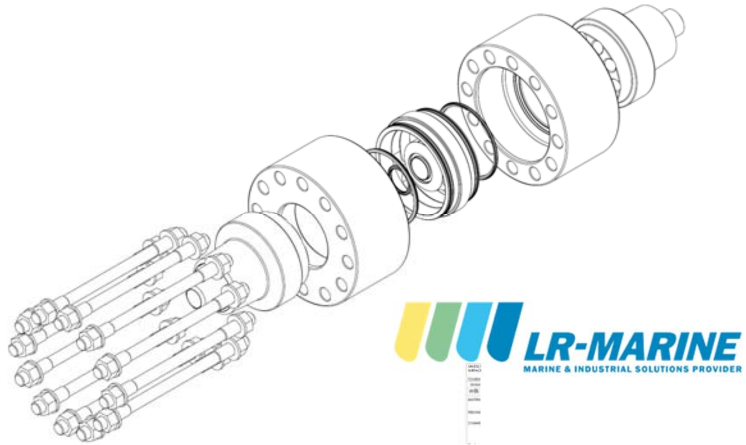
Fixed supported bend, hence smaller outer pipe diameter

Tasks

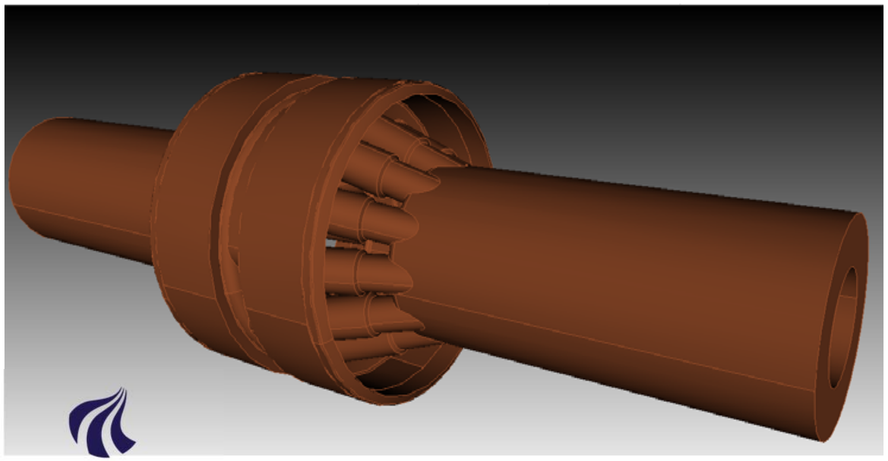
Double Pipe Joint - Computational Fluid Dynamics

CFD simulation:

- CFD was performed on several different configurations of the double pipe joint
- The best design was selected with regards to pressure loss



View of the flow volume of the double pipe join



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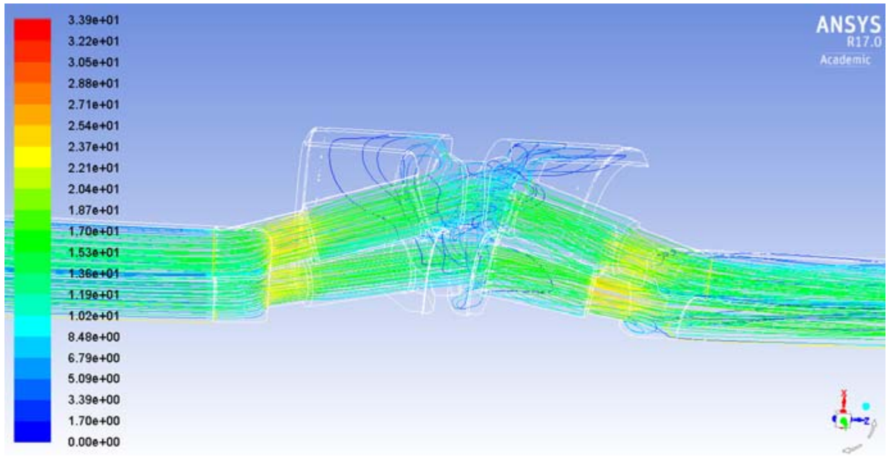
DENMARK

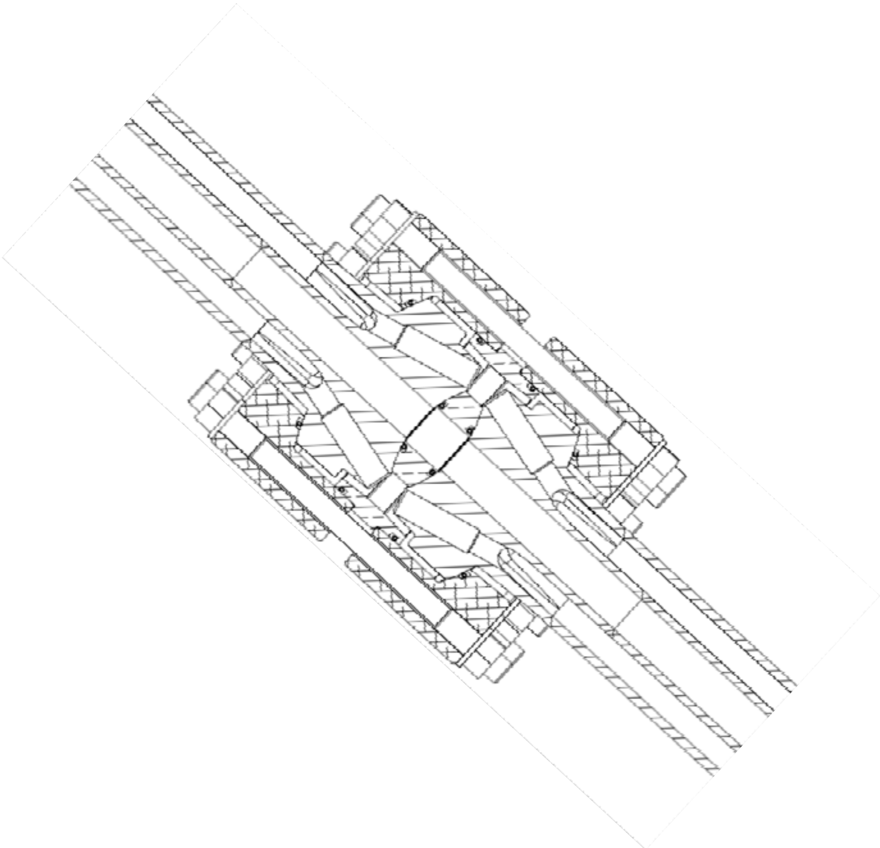


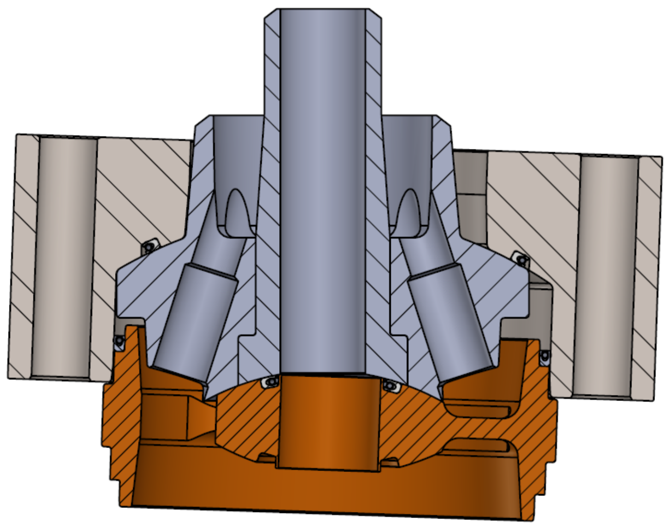
CFD simulation of the double pipe joint

Tasks
Flange Design

Application example:
Pipe connections for fast and stress-free assembly

- SAF2507 super duplex
- Allowing for 2° angular misalignment
- PTFE seals with springs
- 660bar design pressure

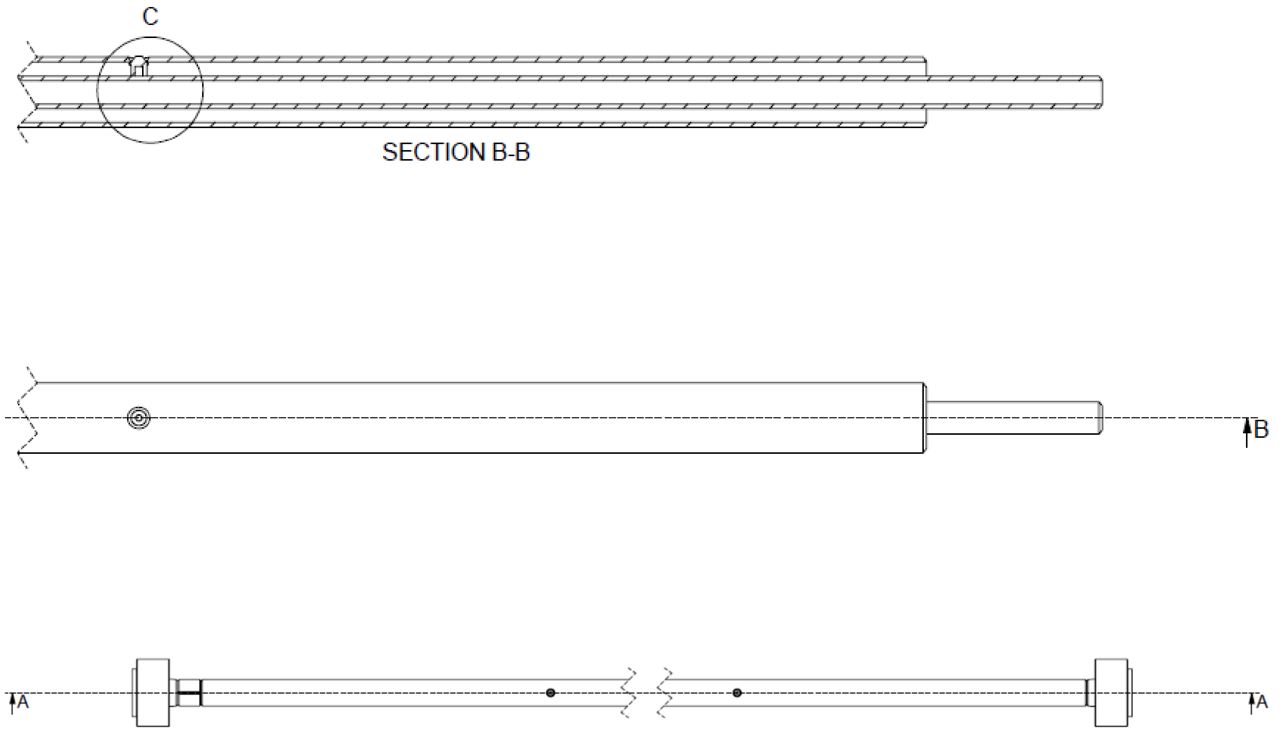


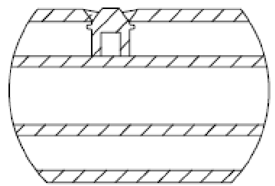


Tasks

Straight Pipe - MAN Double Wall Piping

Simply supported straight pipes and pre-welded modules



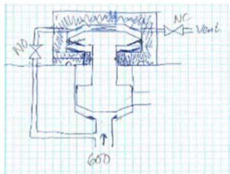


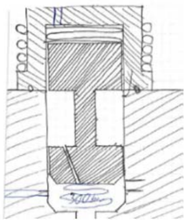
DETAIL C 1 : 2

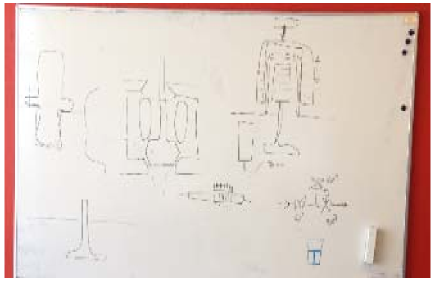
Tasks

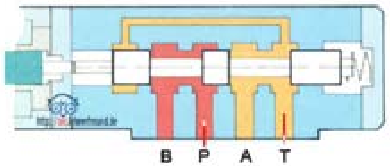
GVT Valve Design

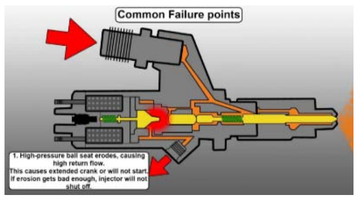
After determining the requirements for the high-pressure valve and GVT, Eltronic initiated an innovation process, which resulted in the chosen valve concept.

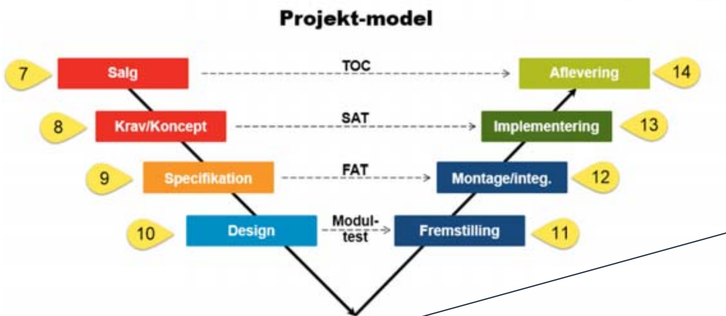


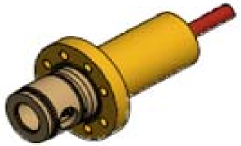


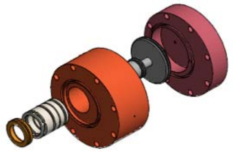


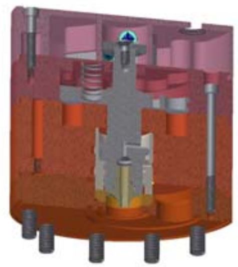












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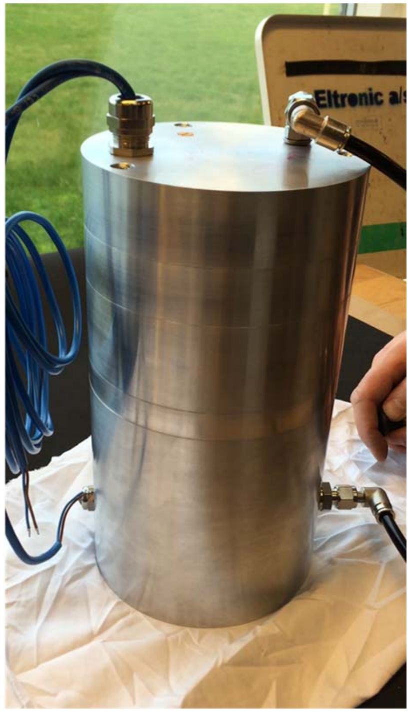
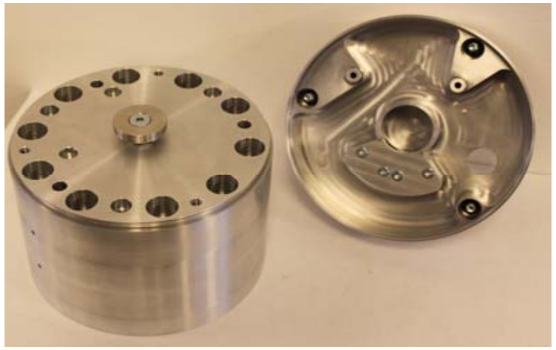
Tasks

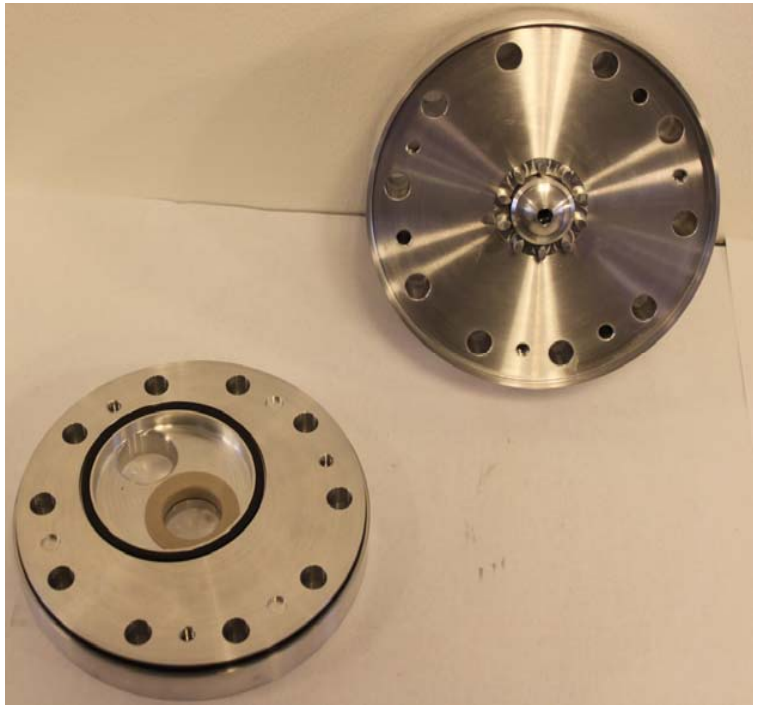
Proof of Concept Test - 1st Prototype Valve

1st Prototype Valve

- To test if the concept was feasible, a low-cost, low-pressure prototype was constructed and tested







Tasks

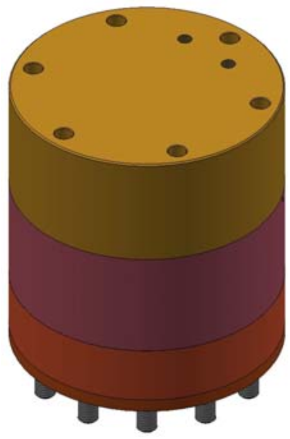
Proof of Concept Test - 2nd Prototype Valve

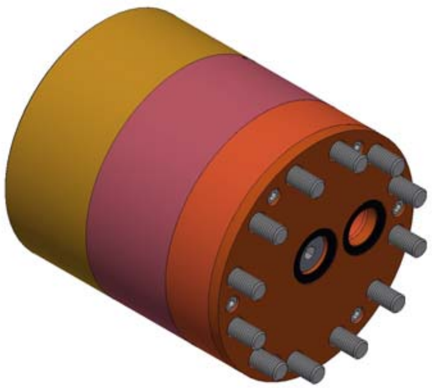
2nd Valve Prototype

- Based on 1st prototype tests and flow simulation, the concept was optimised to reduced number of sealings

- After tests of 2nd prototype, experiencing challenges with material choices of internal components, surface between metal and PTFE parts and balancing of the valve

- Further tests and smaller redesign of valve needed





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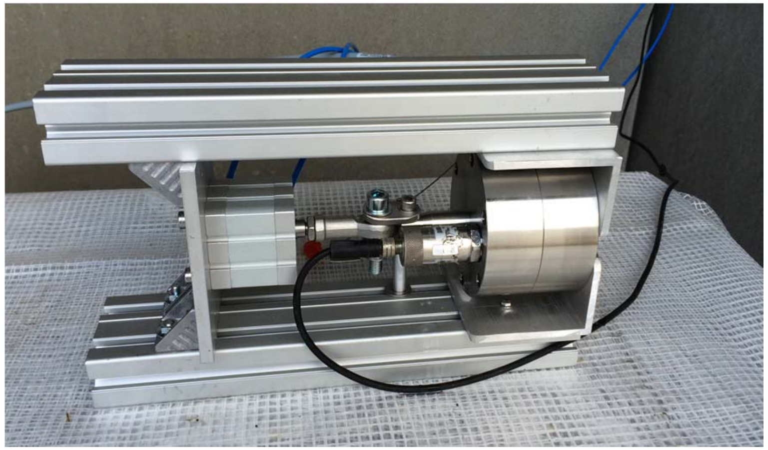
Tasks

Sealing & Surface Treatment Tests

- Test of static & dynamic PTFE sealings at 660 bar(g)
- Tests with different PTFE compounds
- Tests with different surface treatments of dynamic parts



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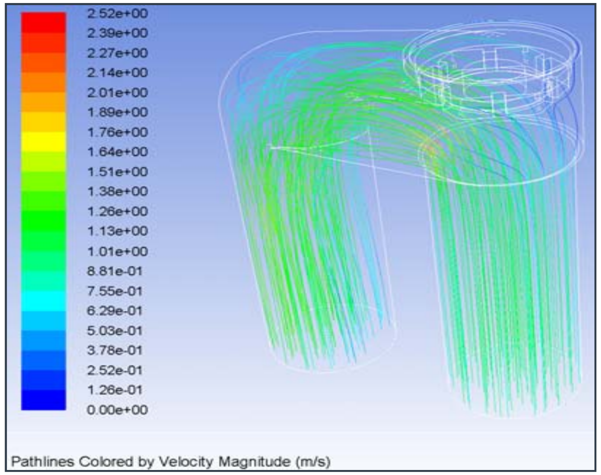
FUELTECH

Tasks

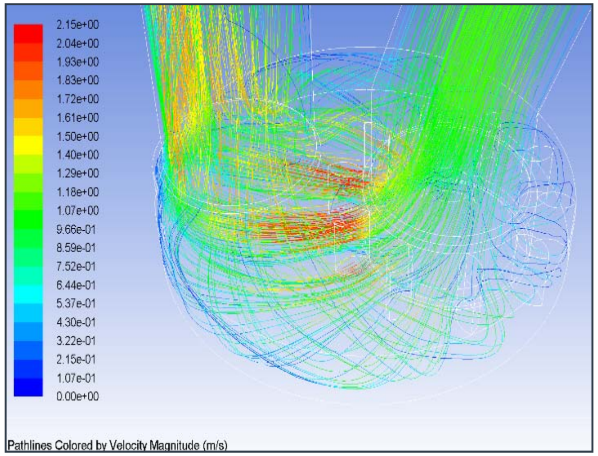
CFD Simulations of the Main Valve

CFD Simulations:

- CFD simulations were performed on several different designs of the main valve
- The loss coefficient of the valve was reduced from 8.5 to approximate 1.6
- Cooperation between Eltronic and AAU Energy resulted in a transference of knowledge of fluid flow to Eltronic



CFD simulation of 2. gen. valve



CFD simulation of 3. gen. valve

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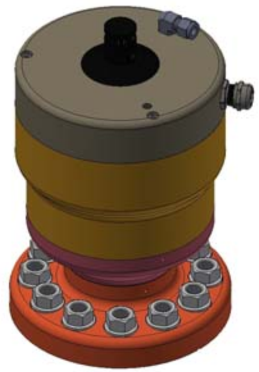
Tasks

Final High-Pressure Valve

- Slimmer design compared to prototypes – weight reduction
- Easy configuration between “normally open” and “normally closed” valve
- Simple mounting
- Manual valve based on same principle

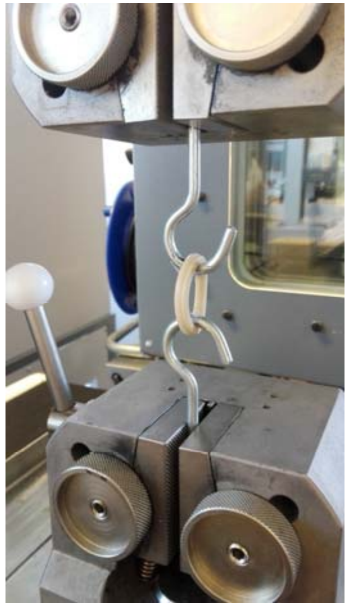


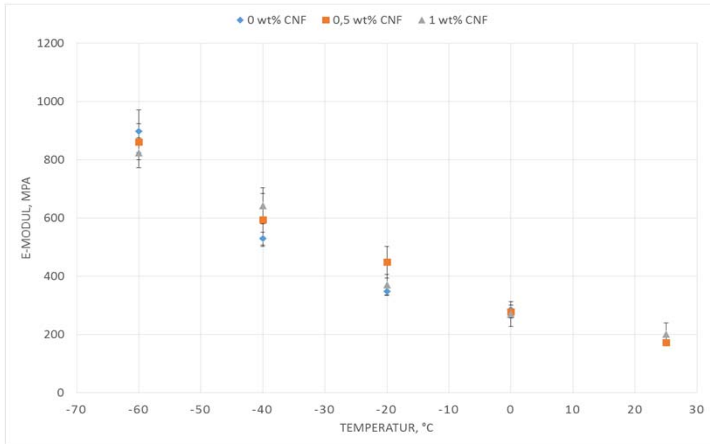
Tasks

Material Investigations

Aalborg University has been involved in several activities with regards to material selection and testing such as:

- Selection of possible materials for low temperature applications
- Characterisation of materials at low temperatures
- Manufacturing of a carbon Nano-fibre polyethylene composite as an alternative material
- Evaluating gasket material after test of the complete system





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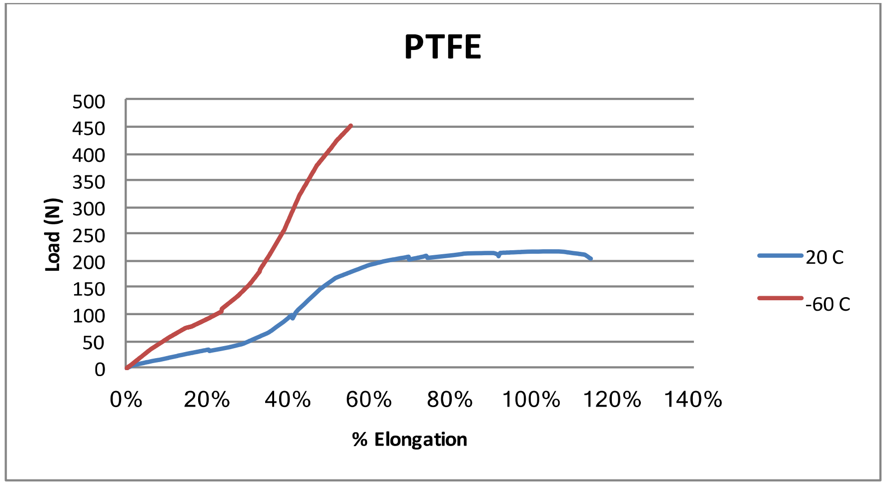
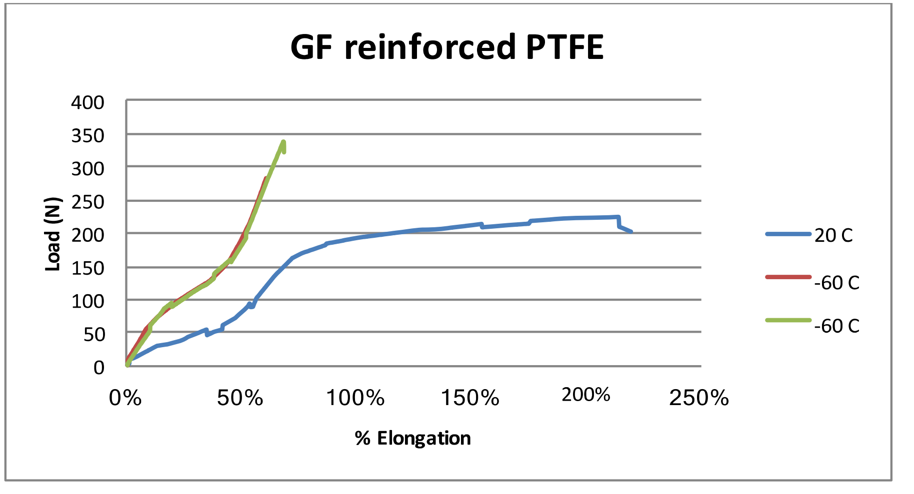
Findings:

- Few materials are compatible with the requirements, especially for polymers maintaining ductility and toughness at temperatures below -70ºC
- PTFE and variations hereof showed reasonable retention of mechanical properties at low temperatures, although with a loss of ductility and increased stiffness





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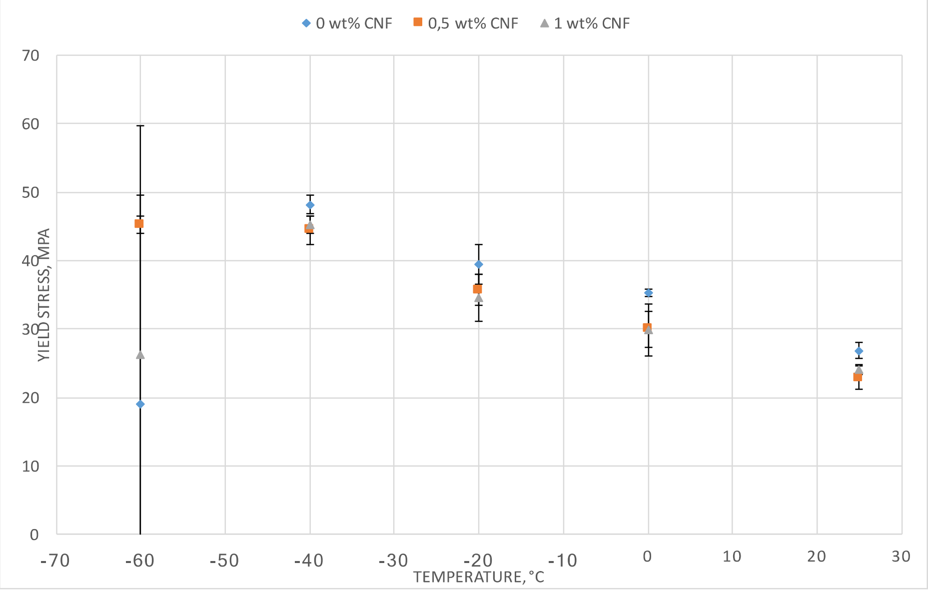
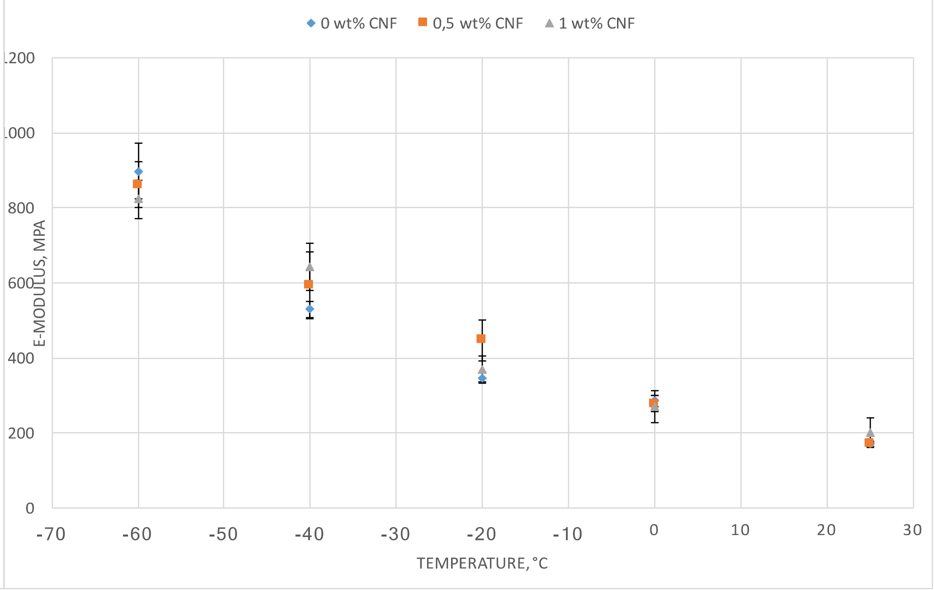
Tasks

Material Investigations

Findings:

- Using carbon Nano-fibres to enhance the cold properties of polyethylene did not provide significant changes to cold properties





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Tasks
Material Investigations

Findings:

- After final testing of the GVT, validation of new and used gaskets was conducted, determining effects on the material according to operation conditions
- This includes most notably mechanical testing to determine if formation of fractures due to pressurisation and depressurisation cycles and temperature changes has occurred

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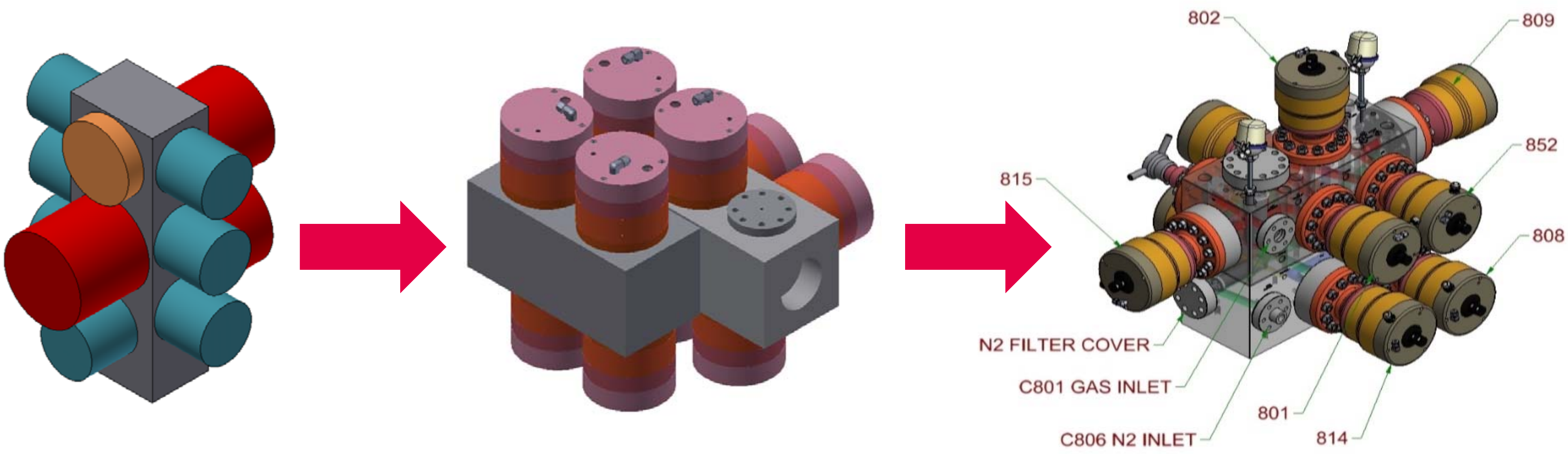
Tasks

Gas Valve Train - Block Concept & Design

Development of gas valve train block concept and design:

Initial concept - 1 gas and nitrogen block (*not possible*)



Tasks

Gas Valve Train - Block Concept & Design

Tasks

Gas Valve Train - Approval in Principle

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Eltronic A/S
Kilde Alle 4
DK-8722 Hedensted

Date 22 November 2017
Your ref 325-00113
Our ref MI116192/1501041/PHE/phe

Inno+ Gas Valve Train

Approval in Principle

This approval in principle is limited to the marine application of the Inno+ Gas Valve Train. The design documents provided so far show no major conceptual issues that would prevent the equipment gaining classification. Detail assessment of the design, and its specific ship board application / location would be subject to the normal rigors of classification approval. It should be noted that this approval in principal does not mean automatic design approval. There may well be significant technical or regulatory challenges which appear when the details of the design, seen in relation to specific application, are considered.

Of the documents reviewed so far, LR has the following comments.

1. The scope of this document is dealing with mechanical and piping system and electrical aspects of the INNO+ GVT Unit only.

2. The equipment would be subject for consideration as component of a general vessel integration risk assessment, as required by GF Ships Rules, Part A, 4.2.

3. It is noted that "Sanmac 2205 (Duplex (1.4462))" is the proposed material for the fuel piping system and that this meets requirements for strength, corrosion resistance and compatibility with low temperatures.

4. Ref. block P-B 13504, it is noted that there is an area where equivalent stresses are exceeding the allowable stress for the material and that the issue is addressed via FMEA ID 52.

5. It is noted that the fuel gas for the Gas Valve Train consists of either nearly pure methane or ethane. Due to high operation pressure, there will be no condensation of heavier components during normal operation of the unit. Condensation of liquid is only likely to occur during blow-down of the system to the atmosphere, but this contingency is considered to be negligible.

6. Where valve No. 801, is assigned as "Main Safety Gas Valve", this will be arranged for operation as per the requirements of LR Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2017, Part A-1, 9.4.3.

7. It is noted that the sensors are tested and verified for 600 bar, ref. Datasheet Siemens Sitrans P220 1000 bar version.

The documents listed below have been reviewed

325-00113 (74 sheets)	**-**	**P&ID GVT Inno+**
325-00113-MFB01	**A**	**Inno+ GVT**
- (17 sheets)	**-**	**Technical Specification**
- (73 sheets)	**-**	**User Manual**
- (3 sheets)	**-**	**Failure Modes and Effects Analysis**
- (10 sheets)	**-**	**Calculation Report P-B-13504 and P-B-13505 Blocks**
- (15 sheets)	**-**	**Calculation Report P-B-13469 and P-B-13542 Covers**
- (21 sheets)	**-**	**Calculation Report A-A-11359 Valve**
- (9 sheets)	**-**	**Calculation Report P-B-13609 Swivel Flange**
- (11 sheets)	**-**	**Calculation Report A-A-11387 Manual Valve**
- (10 sheets)	**-**	**Bolt Strength Calculations - Internal, High Pressure Section**
- (20 sheets)	**-**	**Bolt Strength Calculations - Main Bolts - Valve/Block Assembly**
- (29 sheets)	**-**	**Inno+ Gas Valve Train & Valves, Design Specification**
- (33 sheets)	**-**	**Gas Valve Train - Single Line, GVT Functional - Test Specification FAT**
- (8 sheets)	**-**	**ATEX Risk Assessment Inno+ GVT**
- (2 sheets)	**-**	**EX Component List for Gas Valve Train - Single Line**
- (24 sheets)	**-**	**Risk Assessment, Inno+ GVT**
- (6 sheets)	**-**	**Pipe Strength Calculation**
- (21 sheets)	**-**	**CFD Simulation of High Pressure Valve**
5649042-0 (342 sheets)	**12**	**Engine Control**
5740417-4 (8 sheets)	**01**	**Valve Train - LF Fuel System**
- (4 sheets)	**-**	**FMEA Rating Chart**
-	**-**	**Documentation for Intrinsically Safe Circuit**

8. Interface to MAN ME-GI control system
This is documented in MDT Document Valve Train – LF Fuel System 5740417-4.1 and MDT Electrical drawings Engine Control ME-GI ECS 5-8 5649042-0 pages 84-91 Ch.9 Second Fuel valve Train.

9. FMEA 325-00113&BQB01_00d
It is noted that background for estimation of severity, occurrence and detection, i.e. a reason/description of the levels used and a matrix of acceptable level to measure against, is described in Eltronic document FMEA rating chart.

10. GVT Functional Test Specification_FAT 325-00113&BQA01-01
It is noted that the test herein is partly aligned with the FMEA.
FMEA ID 8,36,47,51 and 52 will be verified in FAT. FMEA ID 1, 2, 3, 4, 6 and 7 will be verified in PT and leak test.

11. Risk assessment 325-00113
According to Eltronic, this is not to be taken into consideration.

12. Control system for FGS and Gas Injection ME-GI
This is documented in MDT Document Valve Train – LF Fuel System 5740417-4.1 and MDT Electrical drawings Engine Control ME-GI ECS 5-8 5649042-0 pages 84-91 Ch.9 Second Fuel valve Train.

13. Ex Component List for Gas Valve Train 325-00113BQB04-01
An intrinsic calculation (front end component – cable – intrinsic barrier power supply) as per IEC 60079-25:2003 for the intrinsic safe components is presented in document Loop Inno.

14. Double block and bleed / Cause and Effect
PID diagrams 325-00113&EFS01-01 PID EL Pneu GVT Inno indicates double block and bleed.
Cause and Effects diagram for conditions leading to valve actions is covered by MDT scope and not Eltronic scope.

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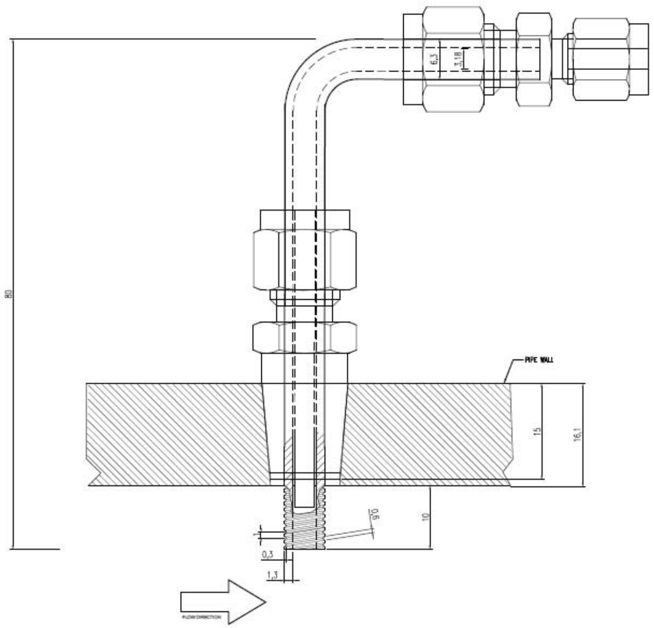
Lloyd's Register Marine

Sample probe / Flow Measurement

- Sample probe designed for high pressure (>500 barg)
- Low sample volume – fast response time
- Welded hubs for integration into piping system

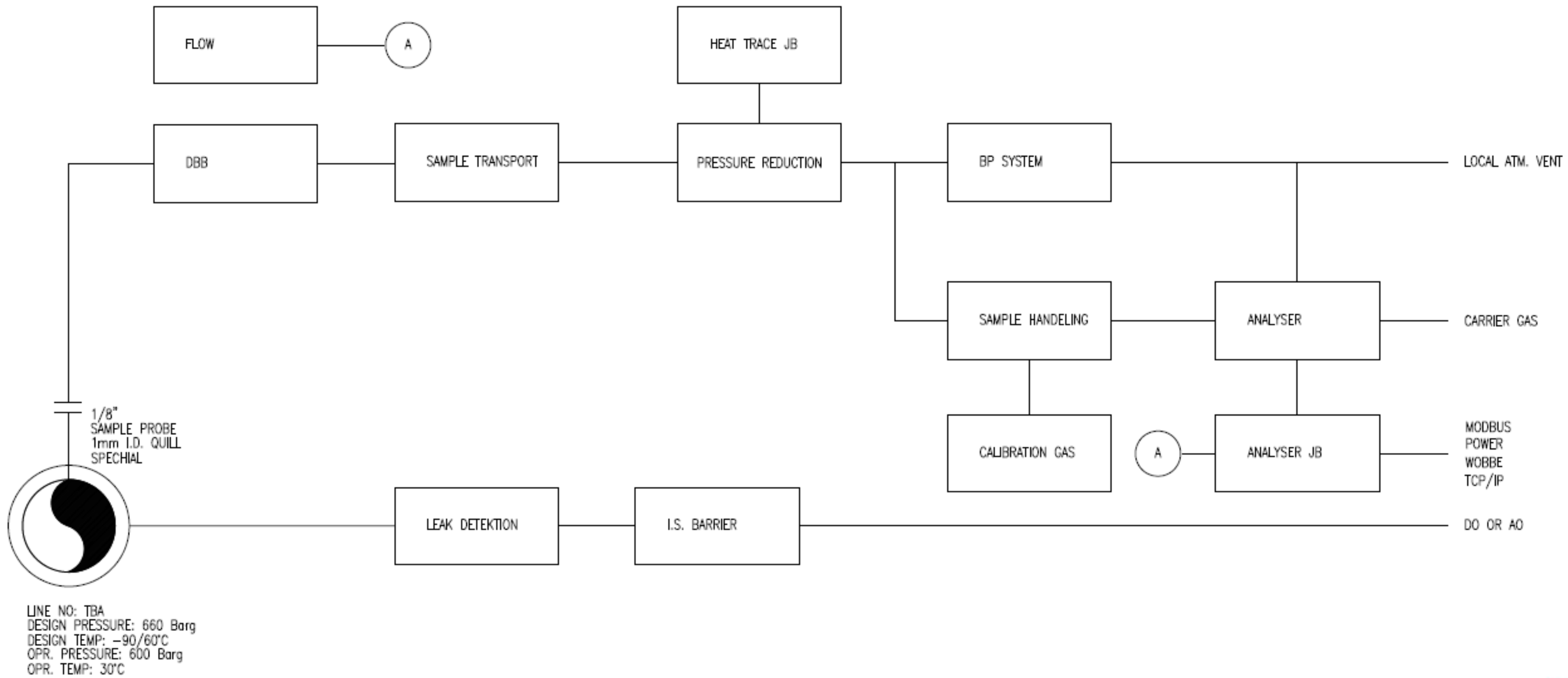


dansk analyse a·s

Tasks

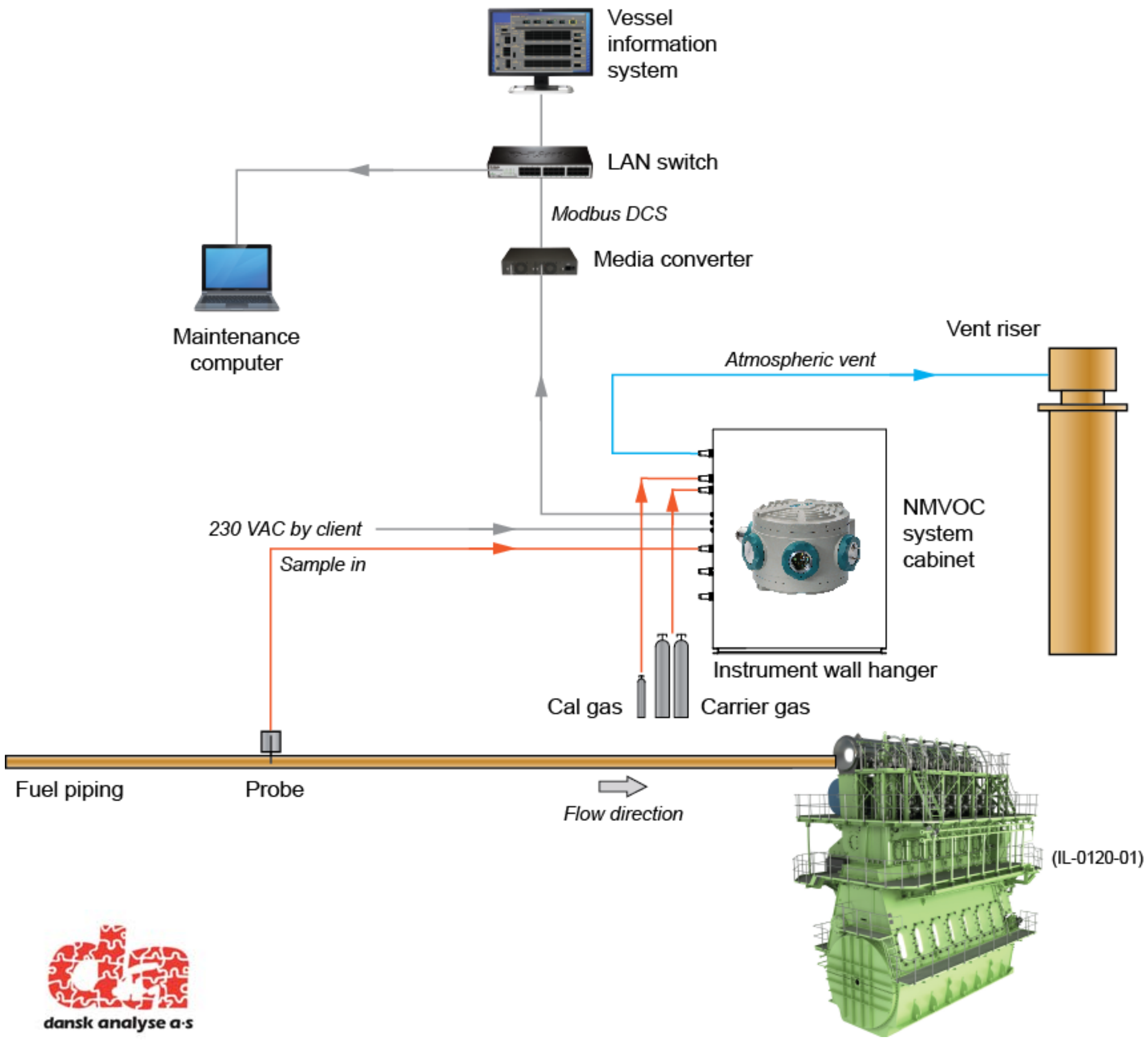
Gas Valve Train - Instrument / Analyser

Block diagram with signals from analyser, flow measurement and leak detection



Tasks

Gas Valve Train - Analyser System



Analyser System

- Pressure reduction in capillary tubing
- Pre-insulated and heated tubing/box
- Automatic sample treatment and calibration system
- Alarm at low flow to analyser system and low carrier gas flow etc.
- Similar system (not high pressure) already type approved by GL-DNV (NMVOC)

Tasks

Gas Valve Train - Analyser System

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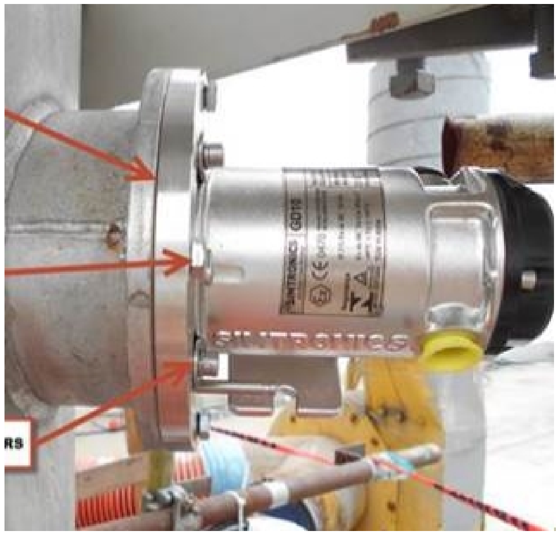
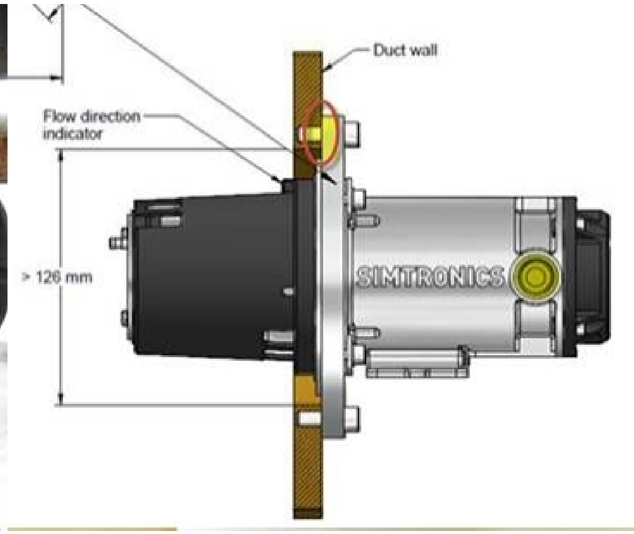
Tasks
Gas Leak Detection

Findings:

- Leak detection based on IR absorption
- Detects small leakages.
- Fast response
- Already installed on several MAN double piping ventilation systems





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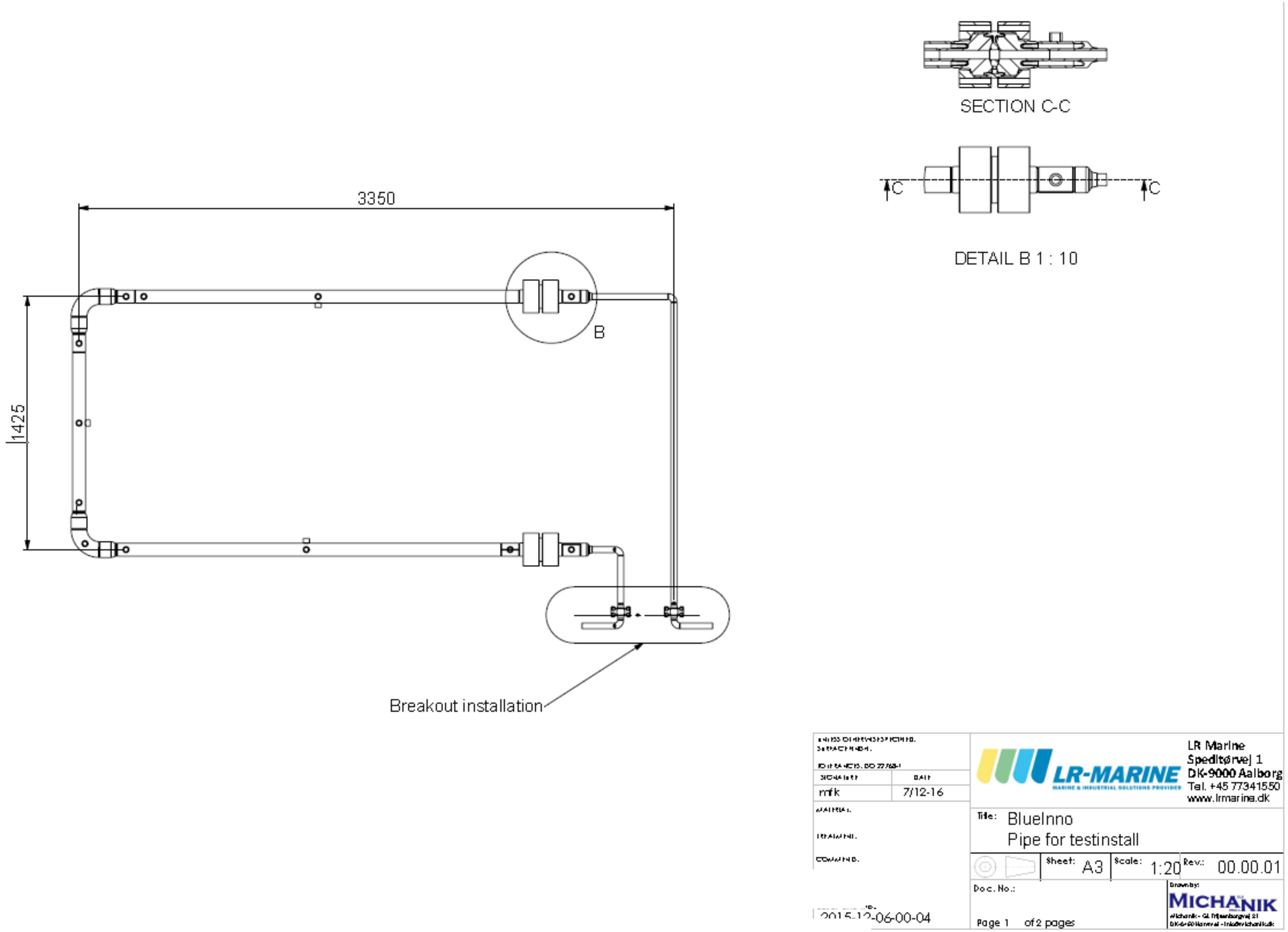
Tasks

Test Installation: Double Wall Pipe - Production Phase



Tasks

Test, Validation and Verification

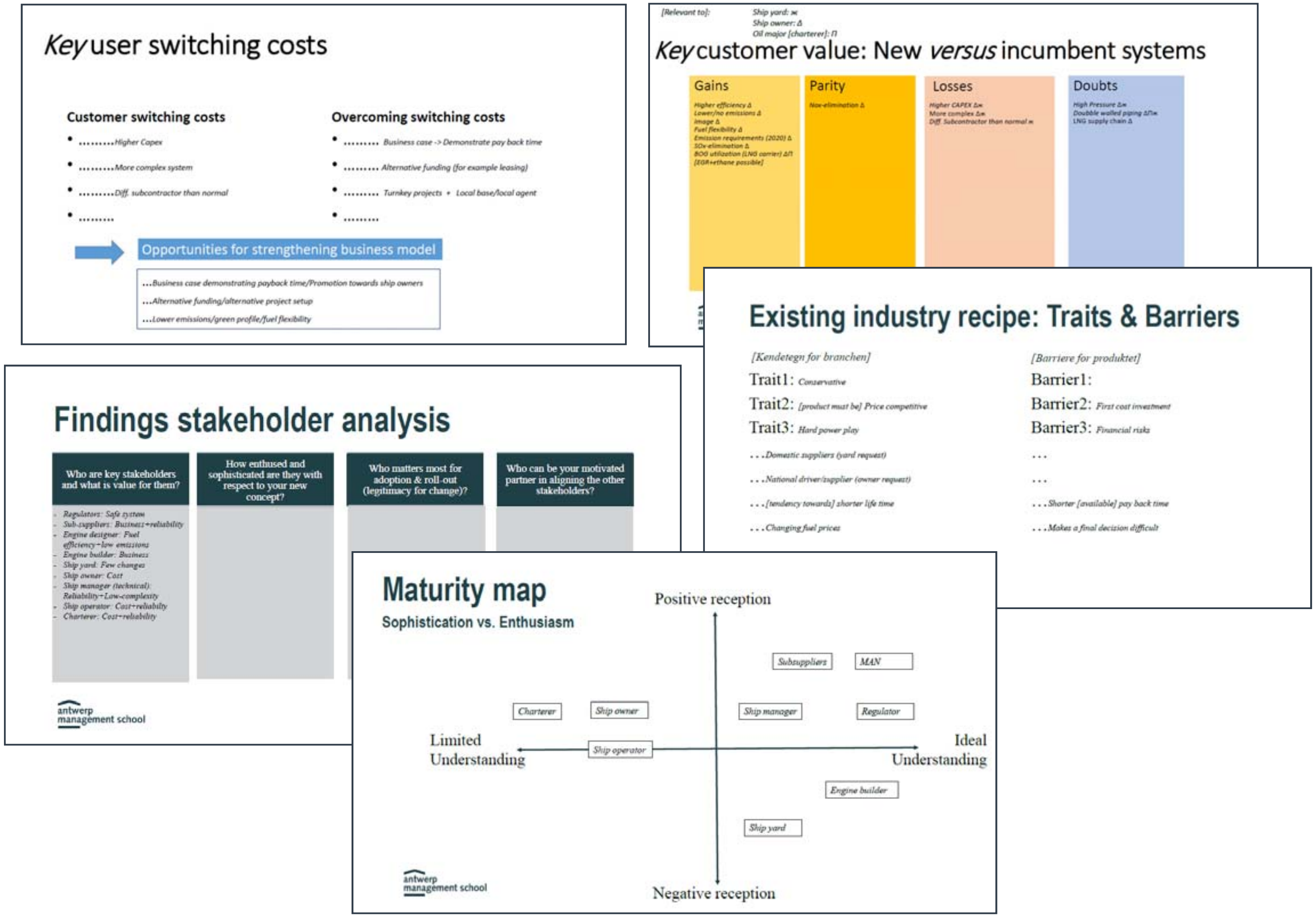
- GVT and the double wall pipe are installed at MAN’s research engine
- Instrumented with sensors and data acquisition is established





Commercialisation

Key Learnings



Commercialisation

Key Learnings

Key learnings from business case workshop

Opportunities for strengthening business model

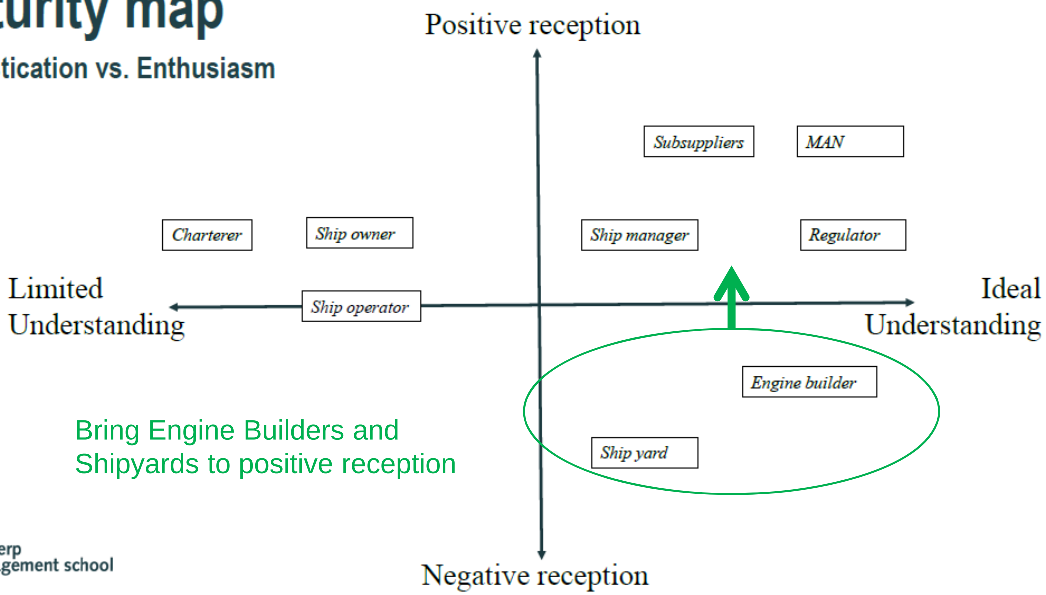
…Business case demonstrating payback time/Promotion towards ship owners

…Alternative funding/alternative project setup

…Lower emissions/green profile/fuel flexibility

Maturity map

Sophistication vs. Enthusiasm



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Who are key stakeholders and what is value for them?

- *Regulators: Safe system*
- *Sub-suppliers: Business+reliability*
- *Engine designer: Fuel efficiency+low emissions*
- *Engine builder: Business*
- *Ship yard: Few changes*
- *Ship owner: Cost*
- *Ship manager (technical): Reliability+Low-complexity*
- *Ship operator: Cost+reliabilty*
- *Charterer: Cost+reliability*

Commercialisation

Key Learnings

- The marine two-stroke engine market trend shows an increase of gas engines from 2 GW/year in 2018 to 7 GW/year in 2028.
- MAN estimates that 8 - 12 % of these gas engines will benefit from the higher fuel pressure of 60 MPa enabled by this project.
- Potential for developing GVT into a commercial product. The 60 MPa GVT first cost is index 150 compared to the present standard GVT.
- The high pressure valve has been presented in Eltronic's product catalogue.
- Potential for developing double wall pipe into a commercial product.
- Gas analyser system ready for commercial applications.

Conclusions

Key Learnings - Management and Cooperation

☺

- Close communication between relevant partners, resulting in future proof products.
- Team work has been established between the partners, leading to extended corporation beyond the INNOship project.
- Changing requirements due to operational experiences and changing market demands, have required flexibility/agility by project partners, who has worked satisfactory towards the end target.

😐

- Project start-up was “slow ahead”, and it took longer time to define the target than expected.
- Roles, responsibilities and required competences were not completely clarified in parts of the project,

Conclusions

Key Learnings - Management and Cooperation

- The GVT could be a new product for the partners in the future.
- The solutions and components are scalable and can be utilised for the present MAN gas engine program. MAN now has the possibility to provide an extended gas engine program with variety of gasses.
- The GVT is not limited to marine applications, but has the potential to be used both onshore and offshore.
- This Blue INNOship project could not have been possible without the joint effort of all the partners of the project, where everyone played an important role in finalising the solution and arriving at a functioning GVT and supply pipe system.